TECHNICAL GUIDANCE DOCUMENT

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Investigation of Manmade Preferential Pathways

Office of Land Quality

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Background

The IDEM Remediation Closure Guide (RCG) issued March 22, 2012, is based on the process of developing a conceptual site model (CSM). The purpose of this guidance document is to provide additional tools to enhance CSM development. This document does not endorse any technologies mentioned in the text. This technical guidance document does not alter any existing IDEM guidance, rule, etc.

Introduction

The following facts, observations, and examples are based on multiple scenarios where manmade conduits greatly influence ground water hydraulics and/or the distribution and extent of subsurface contamination. This listing does not cover every potential scenario or investigative technique. The intent is for informative purposes only.

> Preferential Pathway: A route of least resistance for fluid flow, or a more permeable feature than the surrounding materials. A pathway may extend vertically or horizontally and be derived naturally or by human activities. Feature orientation may be such that fluid flow could go in an unexpected direction. Generally, pathways are limited in width but extensive in length. Examples include improperly sealed wells; field tiles; buried utility lines; and building foundations.

Most remediation sites are in developed areas where humans have greatly altered the original subsurface environment. Human activity also changes areas that are not urbanized. The shallow subsurface in both urban and rural environments is disturbed by drainage improvements, subsurface utilities, and cut and fill for construction. Often these features are unknown prior to the investigation.

Why are Manmade Preferential Pathways Important?

Disturbed sediments are more porous and permeable than naturally deposited ones regardless of their composition and grain size. For example, sand fill is more permeable because it is placed without sorting or compaction to fill a void. Textbook porosity and permeability values assume that materials are uniform and compacted, but these values are not representative of human altered materials.

Manmade preferential pathways can transmit all phases of contaminants tens to hundreds of feet away from the release point regardless of ground water depth. This movement is often in directions up-gradient or cross-gradient of a release. In areas where ground water is deeper than a pathway, vapors may move great distances through porous backfill and conduits. Where shallow ground water is present, product and dissolved phase plumes can travel quickly and without attenuation beyond the property boundary. Preferential pathways can also provide a vertical migration route to deeper aquifer horizons by intersecting and breaching fine-grained layers.

Preferential Pathways and the CSM

Preferential pathway assessment begins before or during the initial investigation phase. A comprehensive CSM considers the operational history and probable contaminant release mechanisms. Often, investigation proceeds forward with delineation from a 'source' without evaluation of how the contaminant reached its distribution in the subsurface. This can lead to wasted effort by misinterpreting the contaminant distribution. The investigator should step back and view the site as a whole rather than only investigating the point of release.

For example, nearly all pre-1980s dry cleaning machines were plumbed to the sewer. Also, petroleum service stations are usually on busy corners near large diameter sewers. These are direct conduits to examine early in the investigation.

The CSM should account for both the presence and characteristics of the preferential pathways with respect to the release area if manmade features are suspected contaminant transport routes. Additional investigation should also seek to understand how preferential pathways may affect the subsurface hydraulic properties. This preferential pathway survey should involve a more comprehensive view of the site layout, the site's surroundings, the local and regional geology and topography, and the degree and age of urbanization in the area.

Preferential Pathway Identification

This section lists the common, subsurface elements which influence NAPL migration, soil source geometry, vapor intrusion, and contaminated ground water flow. One or more of these elements are present at nearly every site:

- Storm/Sanitary Sewers are the most common preferential pathways associated with subsurface contaminant releases. Contamination from subsurface releases enters the more transmissive backfill around the lines. At many dry cleaners and some industrial facilities, the lines are a source area, because wastes discharged into drains or the storm sewer received run-off from surface spills. Storm sewers and many older sanitary lines are leaky and allow contaminated wastewater to enter the subsurface. Sewers should always be assessed, as they are present at nearly all sites. Both main lines and laterals need to be located. Also, floor drains within buildings need to be diagrammed

The sewer or backfill around the sewer line may still influence contaminant distribution even if the ground water table is below the sewer lines. Vapors can travel along porous backfill and conduits to create indoor air issues. Additionally, localized perched aquifers may be associated with the lines, and in some areas sewer main lines can be as much as 30 feet deep. The location and depth of storm and sanitary sewer lines and lateral connections need to be included on site maps. Approximate depths can be obtained by gauging nearby manholes. The sewer should be shown, to scale, on cross sections. The direction the sewer flows and if it flows constantly or intermittently (i.e. near a lift station) is important information as the conduit can move contaminants in directions different from the ground water gradient.

Although sewers are the most common feature associated with manmade preferential pathway flow; there are other kinds of subsurface conduits which may affect contaminant distribution:

- <u>Energized subsurface utility lines (Gas, Water, Electric, Fiber Optic, etc.)</u> are usually not primary pathways because they are not as large, not buried as deep, and not designed to carry water like sewers. However, they are still surrounded by porous backfill which can intercept contaminants. Sometimes they are in the same trench as the sewer lines, which can complicate an investigation. Depending on the size, depth, and location of the lines, they may explain contaminant distribution. The investigator should determine the locations of energized or pressurized lines in order to safely drill at a location (or use a hand auger, air knife or HydroVac, see below).

- <u>Septic Systems and other localized wastewater management systems</u> have many names including "concrete vaults", "dry wells", "oil/water separators" or "water distribution pits." These are common pathways in rural or semi-rural areas similar to sewer lines in urban areas. At sites which have these, the investigator can assume that they are at least a partial source of contamination. Recently urbanized or suburban areas may still have these structures in place even if they are not currently used for wastewater management. They are often used as dry wells to dispose of waste oil and spent solvents.

- <u>Field Tiles and French Drains</u> are a system of clay pipes (tiles) or gravel- filled trenches (drains) that are intended to lower an area's water table for development or farming. Often, these intercept or directly connect to existing storm sewer lines or nearby streams. Tank vaults and other structures may also intersect these features. In older buildings, floor drains may be connected into these instead of a sewer or septic system. They are usually not a factor at small sites or in heavily urbanized areas but historical drainage improvements can cause problems remediating large urban, suburban, or rural facilities when the site history is not researched.

Almost all glacially derived soils in Indiana have been extensively tiled or ditched to allow drainage for building. In rural and suburban areas, the county surveyor's office might be able to provide some information on the type and density of tiles. County soil surveys will also list the natural depth to saturation, and thus the probability of drainage lines.

- Large Filled Areas are present at many sites. All disturbed areas tend to transmit water, vapors, and contamination more readily than natural soils. Large fill areas can be a source of contamination or control ground water hydraulics. Estimating the distribution and nature of fill around a site takes a more wide-ranging investigation.

  Consider the area around the site. Boring logs are sometimes not enough. A thorough Phase I investigation can be invaluable. Reviewing the topographic maps for the area can be a great help, as can current and historical aerial photographs. When available, Sanborn maps provide an excellent description of historical structures and property usage. Sometimes intermittent drainage ways have been filled in. Sometimes, perennial streams have been channelized under urban development and there is no surface expression. Slopes along creek valleys might have been filled to grade.

  The fill material's effects on the contaminant plume depend on the following:
  - The contrast between the fill and the native materials. If sand fill is adjacent to coarse-grained or poorly sorted sand, the pathway is less pronounced. However, well- sorted, fine-grained sands (i.e. dunes) are much more resistant to flow than poured-in backfill. The interface between sandy fill and clayey soils is often an obvious, primary pathway. A large amount of source material may be in the gravel sub-base of parking lots, storage areas, and buildings.
  - The sources of contamination with respect to the fill. Contamination released into the fill tends to stay in the fill. Surface releases are more susceptible to this. Contamination released into natural soil may also collect in fill down-gradient of the source.
  - The distribution and thickness of fill across the site. If the whole site is covered with fill, the investigation is simpler than if only portions of the site are filled. Typically, if only portions of the site are covered, it is to fill in low spots or to make high spots. These areas create pools and drainage pathways for contaminants.

- Existing Foundations including footers and foundation drains are typically affected by contamination in the fill material surrounding the walls and floor. Most commonly, the sub-base is contaminated by seepage through concrete floors in process and storage areas. Thorough site investigation can characterize their effect on contaminant distribution. The existing foundation sub-base, often in concert with interconnected utility lines and backfill, is often a primary source of vapor intrusion in commercial facilities.

- Abandoned Foundations, Basements, and Cisterns act as barriers or pathways to migration.

    - As a barrier: Outside the source area, abandoned basements and subsurface structures can be islands of clean(er) soil/ground water. Borings placed within or directly down-gradient of these areas may lead to misidentifying the extent of contamination.
    - As a pathway: These can be pools of continuing source from a process or disposal area that has been long abandoned.

- Improperly abandoned or installed wells (water, oil, or gas) are usually discovered when contamination unexpectedly shows up in a deeper zone. If an investigator is diligent, historical research and a thorough site walk through may turn up such information as an abandoned pump house, neighbors with wells, or pipes present at the surface. The Department of Natural Resources should be notified when abandoned wells are found (312 IAC 13-10-2).

Preferential Pathway Investigation

** This discussion relates specifically to sewer lines and associated utility trenches.*

As described in the previous section, every developed site may contain manmade alterations which could influence the distribution and migration of contamination. As a part of the comprehensive CSM, all sites need property evaluation which includes basic identification and mapping of subsurface utilities (including the depth).

A properly completed preferential pathway survey usually consists of on-site utility location, a thorough site and vicinity walk through, and (potentially) a telephone call to the municipal department of public works.

Basic preferential pathway information should be presented on site maps and discussed briefly in the CSM as a part of the elimination of potential exposure pathways for closure.

Various qualitative and quantitative lines of evidence are available to further investigate the site conditions if the initial utility survey indicates that preferential pathways could influence contamination. Sites will typically use a combination of methods to achieve characterization.

Qualitative Lines of Evidence

- The location of the source with respect to known sewer main lines and laterals: Active sewer lines and laterals are usually obvious, but their hydrologic effects are often overlooked. When the contaminant source is adjacent to the sewer or directly discharges to the sewer, an investigation of the lines and backfill for source material (regardless of the ground water depth) is needed. If heavily contaminated ground water flows toward a sewer line that is below the water table, the backfill above the sewer trench should be investigated to determine if it is directing dissolved or vapor phase contaminants off-site.

- Irregular distribution of contamination: Contaminant transport through a porous media creates a plume of generally predictable size, shape, and concentration gradient based on the hydraulic conductivity and ground water gradient. It is possible that a preferential pathway is influencing contaminant travel if contamination is much more widespread than the known geology would tend to allow; contamination suddenly "disappears", the magnitude of contamination is disproportionate to known source, or heavily contaminated soil, ground water, or vapors are detected in unexpected places.

- The development and operational history of the site: Original subsurface alterations and drainage may still be in place even if the property has changed usage, relocated process areas and added or removed structures. For example, sites which were originally residential may still have sewer laterals, cisterns, and water wells. There may have been pre-development dumping at the site. The site may lie in an area of previous sand and gravel mining where pits were filled with waste. The sewer or other on-site wastewater management areas need to be fully investigated if the site operations used contaminants in solution or had to store and dispose of chemicals once they were "spent."

- Historical research: Determining the site history is key to finding abandoned subsurface structures. Sometimes there is no obvious surface expression. The original site features may be altered beyond recognition, but fill areas are found by chance during investigation or a pre-development clay tile is penetrated during boring. Careful review of aerial photographs and historical property maps can be very helpful. An assessment of the building construction may find built-on areas and added parcels. These features are common at industrial facilities where processes have changed or moved and in areas which were previously residential prior to commercial development. A telephone call to the department of public works may provide both previous and current utility locations. If those desktop methods are not sufficient, or they cannot satisfactorily explain what is happening, then a non-invasive investigation of the subsurface may help determine whether there are manmade disturbances influencing contaminant travel.

- Geophysical surveys: These are generally the most reliable way to find disturbed areas and subsurface pathways without excavating the entire site. Two types of surveys are commonly used to find and map non-metallic subsurface features.

  - Ground Penetrating Radar (GPR): This technique is better for finding subsurface structures such as tanks, wells, and foundations but can find most features. It is also more suited to smaller areas and locations with surface obstructions.
  - Resistivity/Conductivity: This technique is better for finding changes in soil structure and composition such as trenches and filled areas but can find most features. This method is better suited to large open areas.

If large areas are covered by reinforced concrete, most geophysical methods are unlikely to be successful.

- Direct investigation of pipes: If unexpected pipes or tiles are found during the investigation, there are several methods available to determine if these features need further evaluation.

    - Smoke Tests: Smoke testing will show where air flows through a pipe. It is especially useful for finding open drain traps and near-surface breaks. Usually the fire department and nearby neighbors need to be informed before completing a smoke test.
    - Vacuum Tests: Vacuum tests are useful if there are multiple pipes that may or may not be connected to a nearby source or receptor.
    - Dye Traces: Dyes can determine if water entering a drain connects to sanitary or storm sewers. The local authorities need to be contacted if dye will outfall to a stream.
    - Sewer cameras: These are useful if the line is completely filled with water, a break in the line is a suspected source, or if trying to precisely locate a line.

Quantitative Lines of Evidence

Standard site investigation and the qualitative measures listed above can show that preferential pathways influence contaminants. However, if there are potential receptors the subsurface vapors, soils, and ground water adjacent to utility lines need to be sampled to determine risks. Whether this is necessary depends on the nature of the release, the contaminant toxicity, and the closure strategy. Common reasons to collect data adjacent to a conduit include:

- Source area concentrations for site characterization and risk assessment.
- Soil and ground water quality to complete a pathway elimination assessment.
- Soil gas concentrations moving through conductive materials.

Sampling within preferential pathways

Testing soil samples from the disturbed area around the utility is appropriate when the sewer lines are a known or probable source (usually dry cleaners). The locations for soil samples within the utility backfill will depend on piping layout. Samples should be collected near entry points (drains) and junctions. Surveys of the pipes with a camera, vacuum, or smoke can help determine these locations if they are not obvious.

If ground water is more than a few feet below the pathway base, contamination is often found only beneath the sewer lines where drilling and sampling are problematic. Very little soil source may be accessible outside of the immediate release area.

Vapor samples from the unsaturated zone directly above the lines are typically the best location to determine whether sewers or the backfill around them influence contaminant distribution. Soil gas is a screening level assessment and vapors often emanate from breaks and cracks in the lines. Therefore, multiple samples above on-site and near site conduits will be necessary to help rule out VI risks.

It is occasionally valuable to directly determine the amount of vapor phase or dissolved contaminant within the sewer pipes. This investigative phase is typically performed after vapor intrusion is discovered, but the pathway route and/or source is unclear. Samples from within sewer lines (if not below the water table) can show if contaminated vapors or water flow through the pipe; however, most releases affect the backfill around the lines.

<u>Common field methods</u>

Investigating around utility lines is complicated by the risk of encountering an energized or pressurized line. Often, multiple utilities are placed in the same trench. The municipality will need to be informed when investigating known active water, sewer, or gas line trenches. City utility workers can be an excellent source of information about location and construction of active utilities. Private utility locators will show only the location of subsurface lines, but tell nothing about depth, construction, or conduit condition.

Options which pose little risk to the lines themselves are readily available. Common tools include:

- Hand augers: Best for a limited number of shallow samples or if there are access restrictions (i.e. indoors). These do not work well in areas with heterogeneous debris or gravelly soils. Hand augers are not useful for more than a few samples because they take so long.
- Air knife: Best for multiple shallow samples in variable material. It is only effective to about 5 feet deep depending on the material and is typically used to clear small areas of utilities before drilling. These are not effective if the utilities are very deep, or the fill is very coarse grained or heterogeneous. They are also inefficient if large areas of material need removal.
- HydroVac: Best used to determine the condition of deep utility lines or to open up extensive areas of conduit for investigation. This machine uses high pressure air and water, in combination with a high vacuum truck to remove soils around utility lines. This technique can quickly remove coarse grained and heterogeneous soils down to 25 feet.

Because of potential volatile loss, soil samples collected after air knife or HydroVac events should be taken shortly after completion from undisturbed areas (about 6 inches away).

Occasionally, it is simply not possible to directly sample backfill around utility conduits due to factors such as fragile water lines, high pressure gas lines, high voltage lines, or pipelines. It may be difficult or impossible to acquire a right of way access permit from a municipality or individual. Situations like this are handled on a case-by-case basis.

Influence of Preferential Pathways on Contaminant Transport

Contamination source in sewer pipe or utility trench backfill occurs at sites where wastes were poured down the drain either as pure product disposal or as a result of poor housekeeping. Sewer disposal often leads to disconnected, high concentration contaminant source areas with very small source footprints. Once on-site investigation has shown there is source material in and around drains, the evaluation needs to continue in the conduit flow direction. Pure product can travel some distance through competent pipes. Common leak locations are at T and L junctions, nearby lift stations, and any saddles in the gradient. Once dissolved or adsorbed contamination is found in the conduit, an investigation of potential ground water receptors and the potential for vapor intrusion is needed near each source area.

Dissolved contamination intercepted by utility trench occurs when a release into the subsurface travels down-gradient with ground water flow until it intercepts disturbed soils in contact with the water. This situation leads to plumes which apparently 'end' near utilities despite having high concentrations nearby . To confirm the extent of contamination, the investigator may need to drill directly adjacent to the trench in the down-gradient flow direction *within the preferential pathway* (this is not necessarily the same direction as ground water flow). If investigation shows that contamination is traveling along the trench, there is the potential for discharge of contaminated ground water or vapor intrusion at nearby receptors.

Utilities that control ground water hydraulics are probable in urban areas with shallow ground water, low ground water gradient and large diameter sewer lines. It is particularly notable in areas with fine-grained subsurface materials. Common indicators of utility-influenced hydrology include unexplained low or high water levels in wells next to the utility trench, and wells off-site and outside the utility corridor that dramatically change on-site ground water flow direction.

Fill creates an ephemeral water table for contaminant movement and allows for horizontal fluid transport until there is sufficient head pressure to drive it downwards. If there is an above ground release, this mechanism spreads the source material outward and increases the contaminant footprint. This is a probable cause when there is a very small contaminant source (i.e. sink sized degreaser) and a horizontally extensive shallow soil source. In this scenario, ground water contaminant concentrations may be low to moderate while vapor contamination is extremely high depending on the contrast between native and fill materials. This is a primary concern in buildings with large areas of interconnected, coarse grained sub-base.

Contamination source or transport in drain tiles usually discharge to nearby perennial or ephemeral surface water features. There needs to be an evaluation of surface drainage areas for contaminated sediments or contamination discharging into surface waters once contaminated drainage tiles are found on a site.

Cross-contamination due to wells usually occurs at large industrial facilities with multiple production wells. Typical cross-contamination problems come from wells installed prior to current Indiana Department of Natural Resources grouting and abandonment requirements outlined in 312 IAC 13. Properly installed wells will not allow cross-contamination.

Closure Strategies

This guide is not a comprehensive discussion of remedial or closure methods. Not every site will need a specific remedy to remove the risk from contamination in preferential pathways. However, if preferential pathways significantly affect the ground water hydraulics or vapor flow, they can create difficulties for both active and passive closure strategies. A good investigation using the principles noted above should determine if and how pathways might affect the contaminant movement and concentration. Sometimes, the pathways make remediation easier, because contamination has been contained within a structure or is funneled to a single discharge point. Some of the more common preferential pathway remedial difficulties are listed below:

How do contaminated pathways affect cleanup and closure strategy?

- Closure Levels: Compare observed concentrations from soil samples collected in conduit backfill to migration to ground water screening levels. Exceedances indicate the need to evaluate ground water.
- Overestimating radius of influence: This is one of the most common reasons active remedial systems can fail. Things to monitor during pilot testing are:
    - One or more distant observation points show a much greater effect than nearby points.
    - All extraction or injection influence is concentrated in one direction.
    - Testing is performed only in areas of disturbed soil or backfill rather than native materials.
- Short circuiting: This will show up as nearly instant vacuum or drawdown in a well. Also, unusually rapid arrival of injectate in distant wells for in-situ remedies is a sign of a conduit.
- Underestimating source area or source mass:
    - Removal of a known source such as USTs or a septic tank is planned. During excavation, contaminated clay tiles or a building foundation are discovered and have to be removed.
    - A remedy is chosen without understanding the distribution of high contaminant levels in and around the on-site sewers. After several years of operations and monitoring, contaminant levels remain much higher than predicted because the source was not effectively treated. Additional operation and possibly a different corrective action are necessary.

  Both these scenarios equate to a large, unexpected expense. It is often less costly to know what is going on before starting remediation.
- Vapor intrusion: Standard attenuation factors often do not apply when the contaminant source is a conduit. A direct conduit into a building invalidates the assumption that contaminants rise slowly through a porous media or are diluted over a large area. Borings around a site can indicate low conductivity soils but do not account for manmade alterations. A common way which

vapors can affect buildings is through sewer lines and drains. A coarse-grained fill under and around buildings can also lead to underestimation of risk.

- Plume stability: Continued water flow through a conduit can destabilize contamination. Conduits can also influence the accuracy of perimeter of compliance wells. If the contamination leaves the site through a preferential pathway rather than through down-gradient flow, then the pathway is where monitoring and remediation need to be concentrated.
- Fate and transport models: The assumptions for uniform, homogenous subsurface conditions rapidly break down in the presence of conduit flow. The risk can be underestimated if conduit flow is not taken into account.

How to accomplish remediation of a preferential pathway

Many times specific remediation of a preferential pathway is not necessary to achieve closure. The conduit and associated backfill may simply direct residual ground water contamination, and once the source is addressed, it will attenuate without additional measures. However, if the conduit allows contaminant discharge to a receptor at an unacceptable risk level, it needs to be included in the remedial strategy. As an example, where the tail of a contaminant plume intersects a sewer, the sewer would not specifically need to be addressed unless vapors above acceptable risk levels appear in nearby structures or contaminated water discharges to the surface. Pathway remediation can be as simple as adjusting the location of a few extraction wells/injection points or as complex as a separate, specifically designed remediation system for the conduits. Usually, contaminated pathways not associated with active utility systems are most effectively remediated by targeted removal.

Resources

IDNR Well Rule 312 IAC 13 http://www.in.gov/legislative/iac/T03120/A00130.PDF?

State Coalition for the Remediation of Dry Cleaners, 2010: Conducting Contamination Assessment at Drycleaning Sites; http://www.drycleancoalition.org/download/assessment.pdf

Sewer Smoke Testing: http://ci.santa-rosa.ca.us/departments/utilities/sewer_wastewater/Pages/testing.aspx

Video Sewer Inspections: www.fairfield-city.org/utilities/videoinspections.cfm
www.ci.sunnyside.we.us/services/public_works/sewer_abc/video_inspect.php

Wisconsin Department of Natural Resources, 2000: Guidance for Documenting the Investigation of Utility Corridors; PUBL-RR-649, 9 pages.

USEPA, 1997: Expedited Site Assessment Tools For Underground Storage Tank Sites: A Guide For Regulators: Chapter 3 Surface Geophysical Methods, (EPA 510-B-97-001). http://www.epa.gov/OUST/pubs/esa-ch3.pdf

Further Information

If you have any additional information regarding preferential pathways or any questions about the evaluation, please contact the Office of Land Quality Science Services Branch at (317) 232-3215. This technical guidance document will be updated periodically or when new information is acquired.